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A STUDY OF SOME PROBLEMS INVOLVED IN MEASURING PERFORMANCE IN THE HORSE

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Ralph W. Phillips, G. W. Brier, and W. V. Lambert [1]

Introduction

The primary function of the horse is to perform work, whether that work is done before a plow, along a bridle path, or in various other capacities. The final measure of a horse's ability must, therefore, be recorded in terms of the animal's ability to do the task for which it is maintained.

Objective tests that give some measure of ability to perform work are essential if the results of experiments in the feeding, breeding, and management of horses, designed to be evaluated in terms of performance, are to be measured effectively. Ideally, every horse used in such experiments should be required to do a standard amount of work over a definite and reasonably long period of time at repeated intervals and under carefully controlled conditions which are similar to those existing in actual practice. The test should give some measure of the ease and efficiency with which that work is done and of its effects upon the animal. Such conditions are very difficult to attain. Lacking such complete measures of performance the experimenter has had to rely upon measurements of growth, visual estimates of form and condition, and upon tests of pulling ability or similar measures of performance to which the horse could be subjected in a short period of time.

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1. The authors are indebted to J. O. Williams, associate animal husbandman in charge of the U. S. Morgan Horse Farm, for assistance in the collection of data, and to J. Petrokovsky, assistant scientific aide, who carried out the major portion of the statistical calculations involved.

The object of the present study was to determine the accuracy with which certain tests could be applied, as measured by the variability in the tests when applied to the same horse at different times. The tests applied were designed to measure speed, length of stride, and respiration and heart rate before and after exercise. It is believed that these tests measure at least some characteristics of the horse which are fundamental to its ability to perform work.

Material and Methods

Fourteen Morgan horses were used in this study. The sex, age, and weight of each animal are indicated below:

Name	Sex	Age Yrs.	Weight Lbs.
Mansfield	♂	19	1,065
Goldfield	♂	3	950
Rhyme	♀	15	1,000
Rosemere	♀	15	990
Ulwina	♀	12	1,080
Walla Walla	♀	10	1,135
Damsel	♀	6	975
Fairy Top	♀	4	980
Fawn	♀	4	1,105
Flashlight	♀	4	955
Ebony Maid	♀	22	1,145
Goldette	♀	3	980
Goodgirl	♀	3	980
Gladstone	Gelding	26	995

These animals were bred and for the most part raised and trained at the U. S. Morgan Horse Farm at Middlebury, Vermont. These horses were used for this study because they were broken to harness and saddle, were accustomed to being handled, and were not raising foals or being used in other ways that would interfere with their use in this manner. Examples of the type of horse used are shown in figure 1.

The track used for the driving and riding tests was an oval, 682 feet in circumference, requiring approximately seven and three-quarter laps to total one mile. There was a variation in elevation of about 6 feet from the low to the high point of the track. The surface was a mixture of sand and clay. It was smoothed and rolled at frequent intervals during the tests.

The horses were submitted to three separate sets of tests; (1) Walk in carriage, (2) trot in carriage, and (3) trot under saddle. In all cases the distance covered was one mile. All horses were used in the first two sets and ten in the last one. In each group of tests, each horse used was submitted to the test three times. The data taken included the following:

(a) Speed. In each test the time required to travel one mile was recorded. In addition, the time required for the first, fourth, and seventh laps was recorded.

(b) Length of stride. In each test the numbers of strides required to cover the first, fourth, and seventh laps were recorded. The number of strides was determined by observing the movements of the right fore leg, and were recorded with a hand tally.

(c) Respiration rate. The number of respirations per minute was observed three times immediately before the walking and trotting tests were made, and again during the first, third, fifth, eleventh, thirteenth, and fifteenth minutes following the test. These data were taken only in connection with the walking and trotting tests in carriage.

(d) Heart rate. Observations on heart rate were taken at the same times as the respiration rates, outlined above.

A training cart was used for tests at the walk and trot in carriage. The weight of the load pulled by each horse, including cart, driver, harness, and any necessary ballast, equaled 55 percent of the horse's weight. The type of cart used is shown in (a) and (b), figure 1.

In the tests at trot under saddle each horse carried a load equivalent to 20 percent of its body weight in live weight. In arriving at the live weight equivalent carried by each animal, one pound of dead weight (saddle and ballast) was considered equivalent to 2 pounds of live weight (rider). Two examples of horses in action under saddle are shown in figure 1, (c) and (d).

The analysis-of-variance technique described by Fisher (1) and Snedecor (4) was used in analyzing the data. When interpreting the results presented in the succeeding section it should be kept in mind that the significance of results is relative rather than absolute. Goulden (3) points out that differences are found to be significant or insignificant in relation to the variability arising from a source which is arbitrarily selected according to the interpretation that is to be put on the result. In this study the primary problem was how consistently the individual horses responded to any given test. Differences between horses were incidental, although the analysis does show the significance of the variance due to differences found between horses in the group used in this study.

Experimental Results

The results obtained from the tests of speed, length of stride, normal respiration and heart rates, changes in respiration and heart rates during exercise, and recovery following exercise are presented in the respective sections below. The average speed and length of stride of the individual horses in the various tests and the normal respiration and heart rates (taken before the trot in carriage) are presented in table 1. These data are presented to give some indication of the individual variability in the group of animals upon which the tests were made.

Only two complete examples of the analyses of variance are given to show the general form of the analysis, the remaining results being presented in summary tables and discussion.

Table 1.- The speed and length of stride of individual horses in various tests, and the normal respiration and heart rates

Horse	Average time for 1 mile			Average length of stride at			Normal respiration rate per minute	Normal heart rate per minute
	Walk (carriage)	Trot (carriage)	Trot (saddle)	Walk (carriage)	Trot (carriage)	Trot (saddle)		
	Minutes:Seconds	Minutes:Seconds	Minutes:Seconds	Feet	Feet	Feet	Number	Number
Mansfield	16:31	4:48	4:32	5.0	11.3	11.3	24.4	39.6
Goldfield	16:08	5:34	5:41	4.9	10.0	9.8	13.8	37.8
Rhyme	16:09	5:58	5:15	5.4	8.8	9.5	11.6	36.7
Rosemere	14:57	5:42	5:12	5.5	9.4	10.6	20.9	38.1
Ulwina	15:54	4:46	4:26	5.1	10.7	10.8	22.2	31.9
Walla Walla	14:10	5:07	4:47	5.7	10.3	11.1	20.0	30.9
Damsel	15:52	4:41	4:13	5.0	11.2	12.3	23.1	31.6
Fairy Top	16:02	5:47	5:19	5.0	8.9	9.6	13.8	36.3
Fawn	16:47	5:00	5:20	4.4	10.5	9.7	16.7	35.9
Flashlight	16:01	4:56	4:47	4.8	10.4	10.7	24.7	40.4
Ebony Maid	16:45	7:29	---	5.4	7.3	---	13.2	41.8
Goldette	15:45	5:31	---	4.9	9.5	---	18.8	38.3
Goodgirl	16:12	5:47	---	5.0	8.9	---	13.1	38.6
Gladstone	18:37	7:13	---	5.3	7.8	---	10.7	34.9

Tests of walking and trotting speed

For the measurement of speed the analysis was actually made on the time required to travel a certain distance, which is proportional to the reciprocal of rate. It is conceivable that different results might be obtained by the conversion of time into the variable rate, by changing the form of the distribution, but for practical purposes the analysis of time should serve the purpose.

Table 2 shows how the analysis was set up for the time required to walk one lap, pulling a training cart. Individual times were taken on only three of the 7 and 3/4 laps required for the mile. There was no significant difference between the means of the laps when compared with the triple interaction. There is no significant lap x test interaction but the significant horse x lap interaction shows that there is a significant difference in the response of the horses to the 3 laps over the three tests. The significance of the horse-test interaction is important. It indicates a differential response of the horses to the tests given on separate days. There was a significant difference between horses used in the experiment when tested against this interaction, but on a more uniform group of horses this significant horse-test interaction might make it impossible to detect differences between the horses used.

The total time required to walk the mile by each horse was also taken. Using these total times, rather than times on individual laps, the analysis shown in table 3 was made. Here there is no measure of the significance of the horse-test interaction, and the horse-test interaction can only be used to measure the significance of differences

Table 2.- Analysis of variance of walking speed (individual laps)

Sources of variance	Degrees of freedom	Sum of squares	Mean square	F
Between means of horses	13	7,001.5949	538.5842	9.38**
Between means of laps	2	20.9047	10.4524	1.52
Between means of tests	2	93.4761	46.7381	1.23
Interactions				
Horse x test	26	1,493.1900	57.4303	6.33**
Horse x lap	26	412.4181	15.8622	1.75*
Lap x test	4	47.3335	10.8334	1.19
Horse x lap x test	52	472.0113	9.0771	
Total variance	125	9,540.9286		

Table 3.- Analysis of variance of walking speed (total time for one mile)

Sources of variance	Degrees of freedom	Sum of squares	Mean square	F
Between horses	13	139,264.497	10,712.6536	8.29**
Between tests	2	3,793.00	1,896.50	
Horse x test interaction	26	33,613.003	1,292.8078	
Total variance	41	176,690.5000		

* Significant
** Highly significant

between horses and between tests. However, it is noted that the variance ratio, F, for between horses, is about the same as the corresponding ratio in table 2.

A similar analysis was made on the speed at the trot in carriage and at the trot under saddle. The results are summarized in table 4. For the tests at the trot in carriage a highly significant difference between horses was found, as well as a highly significant horse x test interaction. For the tests at the trot in saddle a highly significant difference was found between horses but no significant interactions were found, indicating that the horses were performing consistently in the different tests.

Table 4.- Analysis of variance for speed

Source of variance	Type of test					
	Trot in carriage			Trot in saddle		
	Degrees of freedom	Mean square	F	Degrees of freedom	Mean square	F
Between						
Means of horses	13	381.3	21.13**	9	115.1	15.66**
Means of laps	2	7.7	1.58	2	20.6	2.00
Means of tests	2	2.6	6.95	2	11.9	1.15
Interactions						
Horse x test	26	18.0	6.70**	18	7.3	1.20
Horse x laps	26	2.9	1.06	18	4.3	1.42
Laps x test	4	4.9	1.81	4	10.3	1.68
Laps x horse x test	52	2.7		36	6.1	

** Highly significant.

Tests of length of stride

An analysis similar to that used in the preceding section was used with number of strides per lap instead of time per lap as the variable. The number of strides per lap was recorded for the first, fourth, and seventh laps of each test. The results are summarized in table 6. Highly significant differences between horses were found in all of the three sets of tests. Differences between the means of laps were highly significant for the tests of walk and trot in carriage, but not for trot in saddle. The averages of all horses for the three laps, based on three tests for each horse, are given in table 5.

Table 5.- Average number of strides per lap for all horses in the three tests

	Number of strides per lap		
Lap	Walk, in carriage	Trot, in carriage	Trot, in saddle
1	136.98	73.31	66.57
4	134.31	71.43	64.17
7	132.81	71.14	64.43

These data indicate that, on the average, the horses tended to increase their length of stride as the test progressed, except that this trend did not hold for the 4th and seventh laps in the tests of trot in saddle.

Highly significant horse x test interactions were found in the tests at walk and trot in carriage, indicating that in a less variable group of horses this source of variance might be sufficiently large to make it impossible to detect differences between horses. This source of variance was not significant in the tests at the trot in saddle.

ble 6.- Significance of variance from different sources in length of stride at walk and trot in carriage, and trot in saddle

urce of variance	Type of test								
	Walk, in carriage			Trot, in carriage			Trot, in saddle		
	Degrees of freedom	Mean square	F	Degrees of freedom	Mean square	F	Degrees of freedom	Mean square	F
tween									
Means of horses	13	785.5	30.61**	13	854.5	41.34**	9	258.7	18.89**
Means of laps	2	187.1	19.17**	2	56.20	6.78**	2	51.9	3.79
Means of tests	2	108.2	4.21*	2	20.01	1.03	2	17.4	1.27
teractions									
Horse x test	26	25.7	3.59**	26	20.67	4.22**	18	11.5	1.69
Horse x laps	26	9.8	1.36	26	4.69	1.04	18	9.9	1.46
Laps x test	4	9.5	1.33	4	8.29	1.69	4	13.7	2.00
Laps x horse x test	52	7.2		52	4.90		36	6.8	

Normal respiration and heart rates

Respiration and heart rates were observed three times on each horse before making each of the tests at the walk and trot in carriage. The results of the analysis of variance on these data are presented in table 7.

The significance of differences between tests and of the horse x test interaction shows that the respiration rate for the horses was not the same in all tests, but there was no significant difference between the levels of the three observations because of the size of the test x observation interaction. The horse x test interaction was highly significant before both the walking and trotting tests, indicating that with a less variable group of animals the differences between means of horses might not be detected.

There was a significant difference between horses in heart rate before the walking test, but a highly significant horse x test interaction for both sets of tests shows that there is a significant difference in the response of the horses to the different tests.

The term "normal" must be used advisedly in connection with respiration and heart rates. When taking the records before the walking tests the horses were led from their stalls and tied at the harnessing place, a distance of from about 6 to 15 feet from the various stalls. It was felt that this movement was disturbing the respiration and heart rates somewhat, so these records were taken before the horses were moved from their stalls prior to the trotting tests. When the observations taken before the walk and trot were combined into one analysis, highly significant differences between the means of the two sets of tests were found. The respiration and

heart rates were both higher and more variable before the walking tests. These findings indicate the need of standardized and carefully controlled conditions if true pictures of normal respiration and heart rates are to be obtained, especially when working with so-called "hot-blooded" horses that are inclined to be nervous and excitable.

Table 7.- Analysis of variance in normal respiration and heart rates

Source of variance	Degrees of freedom	Normal respiration				Normal heart rate			
		Before walking tests		Before trotting tests		Before walking tests		Before trotting tests	
		Mean square	F	Mean square	F	Mean square	F	Mean square	F
Between									
Means of observations	2	24.5	1.13	2.2	5.48	7.0	1.13	16.9	1.90
Means of horses	13	413.1	2.97**	221.9	3.37**	262.2	2.68*	100.1	1.53
Means of tests	2	1285.4	9.24**	247.4	3.76*	59.7	1.64	26.6	2.47
Interactions									
Horse x test	26	139.1	38.45**	65.9	18.28**	98.0	26.48**	65.6	8.96**
Horse x observation	26	6.7	1.85*	5.0	1.40	7.8	2.12**	8.9	1.21
Test x observation	4	21.6	5.96**	11.8	3.27*	1.9	2.00	5.0	1.45
Test x horse x observation	52	3.6		3.6		3.7		7.3	

Change in respiration and heart rates due to exercise

The mean of the three observations taken before each test of walking and trotting speed in carriage was compared with the observation taken during the first minute following the test. The results are summarized in table 8. The term "between means of observations" in this table refers to the difference between the average of three observations before exercise and the first observation after exercise. As would be anticipated, this source of variance was highly significant for respiration and heart rates in both the walking and trotting tests.

The source of variance "between means of horses" refers to differences between the levels of horses as determined by the average of the rates before and the rates after exercise, thus it does not show differential responses of the horses during a given amount of exercise. The presence of differential responses is shown by the horse x observation interaction and this source of variance is significant for respiration rate at the trot and the heart rate at the walk, indicating that the two tests affected some horses more than others in respiration rate and heart rate, respectively.

Differences between means of tests were highly significant and significant, respectively, for respiration rates at the walk and trot, and significant for heart rate at the walk, indicating that some uncontrolled factors were affecting the levels of these tests.

The significant test x observation interaction for heart rate increase during the trot shows that the effects of exercise were not the same in each of the three tests.

The average increase in respiration and heart rates for each horse during the walking and trotting tests, as well as the average increases for all horses, are shown in figures 2 to 5.

Table 8.- Analysis of variance of the observations on respiration and heart rates taken before and one minute after exercise

Source of variance	Degrees of freedom	Respiration				Heart rate			
		Walk		Trot		Walk		Trot	
		Mean square	F	Mean square	F	Mean square	F	Mean square	F
Between									
Means of observations	1	12,556.3	131.33**	74,822.0	181.93	4,458.9	57.75**	43,384.3	58.77**
Means of horses	13	328.2	3.43	322.6	1.27	209.2	2.71*	192.4	1.40
Means of tests	2	960.3	11.91**	821.8	3.32	142.5	3.49*	558.1	1.32
Interactions									
Horse x test	26	80.6	1.27	139.1	1.23	40.8	1.66	269.7	1.68
Horse x observation	13	95.6	1.51	411.3	3.64**	77.2	3.15**	158.2	1.02
Test x observation	2	6.3	10.00	247.7	2.19	25.1	1.02	738.2	4.59*
Test x horse x observation	52	63.3		112.9		24.5		160.7	

Changes in respiration and heart rate following exercise

Observations on respiration and heart rate for each horse were made at six definite periods during a fifteen minute interval following exercise, and the results of an analysis of variance of these observations are summarized in table 9.

The respiration and heart rates would be expected to decrease somewhat following exercise and the highly significant differences between means of observations show that changes were taking place. The average changes for each horse, and the average rates of change for all horses used, are shown in figures 2 to 5.

The highly significant differences between the means of horses in respiration and heart rates following the walk, and the significant difference between horses in respiration rate following the trot indicate differences in average levels for the various horses, but do not imply differences in rate of change or recovery to normal. Differences in the latter respect would be indicated by the horse x observation interaction and this was significant only for heart rate following the walk.

The differences between means of tests, found to be significant or highly significant for all cases except the heart rate change following the walking tests, indicate that uncontrolled factors were causing differences in general levels of the three tests conducted on respiration rate following walking and trotting and heart rate following trotting tests.

The horse x test interaction was highly significant in all cases and for heart rate following the trotting test was sufficiently large to render insignificant any differences that existed between the means

of horses. These highly significant horse x test interactions indicate that the horses did not always respond in the same degree to repeated tests.

Table 9. - Analysis of variance of respiration and heart rates following exercise

Source of variance	Degrees of freedom	Respiration				Heart rate			
		Following walk		Following trot		Following walk		Following trot	
		Mean square	F	Mean square	F	Mean square	F	Mean square	F
Between									
Means of observations	5	1,154.7	21.21**	6,917.7	36.67**	572.5	24.47**	7,881.8	78.94**
Means of horses	13	1,716.7	8.32**	2,232.1	2.22*	747.9	7.90**	963.8	1.28
Means of tests	2	2,412.9	11.70**	5,678.2	5.65*	254.0	2.68	5,867.2	7.79**
Interactions									
Horse x test	26	206.2	4.24**	1,005.3	7.21**	94.6	5.68**	753.0	6.88**
Horse x observation	65	54.4	1.11	162.3	1.16	23.4	1.40*	99.8	1.10
Test x observation	10	40.3	1.21	188.7	1.35	15.0	1.11	99.4	1.10
Test x horse x observation	130	48.7		139.4		16.7		109.4	

* - Significant
** - Very significant

Discussion

The results of the tests for walking and trotting speed in carriage show that the horses used in these tests failed to respond the same in separate tests. On the basis of these observations it is apparent that several tests under carefully controlled conditions would be required to get a good measure of a horse's performance in these respects. For some reason, the horses performed more consistently at the trot in saddle than when tested for speed in carriage.

In the measurement of length of stride the horses behaved differently from test to test, and also varied considerably within a test, with a tendency to increase their stride as each test progressed. As in the case of measurement of speed, the horses showed less variation in length of stride under trot in saddle tests than in carriage tests.

Considerable care is needed in determining the "normal" respiration and heart rates. Even under supposedly controlled or standard conditions, where measurements were taken on horses remaining in their stalls, it was found that significant differences occurred between respiration rates taken on different days. Removing the horses from the stalls before obtaining the respiration and heart rates increased the observed variability in both respiration and heart rates. This fact emphasizes the great need for standardizing the conditions under which tests are made.

The average heart rate was raised approximately 33 percent after walking one mile and the respiration by 112 percent. In case

of trotting under carriage the respective percentage increases were 122 and 328. The actual changes are shown in figures 1-4. The analysis shows that the same test will not produce the same amount of change in these rates on all horses. In the respiration test at the trot the horse-observation interaction was highly significant as was the horse-observation interaction for the heart rate at the walk. The differential response of the horses to exercise is shown in figures 1-4 by the crossing of the lines connecting the "normal" with after exercise observations. If the increase were the same for each horse these lines would be parallel.

Figures 1-4 also show the rate of decrease of respiration and heart rates following exercise. As would be expected, the analysis of variance shows a highly significant difference between the means of the observations taken at the six intervals during the 15-minute period after exercise. That the change in respiration rate and heart rate is about the same for all horses is shown by the small size of the horse x observation interaction (table 9).

From the results it is evident that tests designed to measure speed, length of stride, and respiration and heart rate are subject to rather wide variations when applied to the same horse at different times. It is apparent, therefore, that, if such tests are used for the purpose of detecting differences between horses, the tests must be repeated several times under carefully controlled conditions. However, the degree of accuracy required will depend upon the magnitude of the differences that it is desired to detect. In most of

the analyses presented here, the variability of the material used (i.e., of the 14 horses) relative to the various sources of error was high enough that the observed differences between horses were significant. In a more uniform group of horses it would probably be necessary to improve the accuracy of the test in order to differentiate with any degree of certainty between animals with respect to any given character.

It should be emphasized that the results presented in this bulletin deal only with the degree to which results of each of the tests agree when obtained on the same horses at different times. Before these tests, or any other tests of performance, should be applied generally, careful studies are needed to determine the relationship of the tests to actual performance under practical working conditions. The development of performance tests and the extent to which they are being used at present have been thoroughly reviewed by Gehring (2), along with presentation of a considerable amount of basic material on circulation and respiration in relation to performance.

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(2) Gehring, Klaus. 1939. Untersuchungen über Kreislauf und atmund im hinblick auf die leistungsprüfung des pferdes. Zeitschrift für Tierzüchtung und Züchtungsbiologie 42: 317-428.

Summary

In order to determine the variability of data from tests applied to the same horses at different times, a series of observations were made on 14 horses at the walk and trot in carriage and on 10 horses at the trot in saddle.

Analysis of variance on these observations led to the following conclusions:

1. For speed at both the walk and trot as well as in length of stride there was a significant variation between tests of individual horses.
2. There was a progressive tendency for the horses to increase the length of stride in the later laps of the same test, although this trend was not so pronounced in case of the trot in saddle. This clearly indicates the need for making observations under similar conditions if comparisons are to be made between individuals.
3. The variability of the observations on respiration and heart rate made previous to the tests indicates difficulties in defining a "normal" respiration and heart rate. This emphasizes the need for making such observations under very carefully controlled conditions.

4. The extent of increase in both the heart and respiration rate is dependent upon the amount of exercise as well as upon the individual horse. The rate of return to normal respiration and heart rate following exercise, likewise, is dependent upon the amount of exercise as well as upon the individual horse.

These findings are discussed in relation to the development of tests designed for the measurement of performance in horses.

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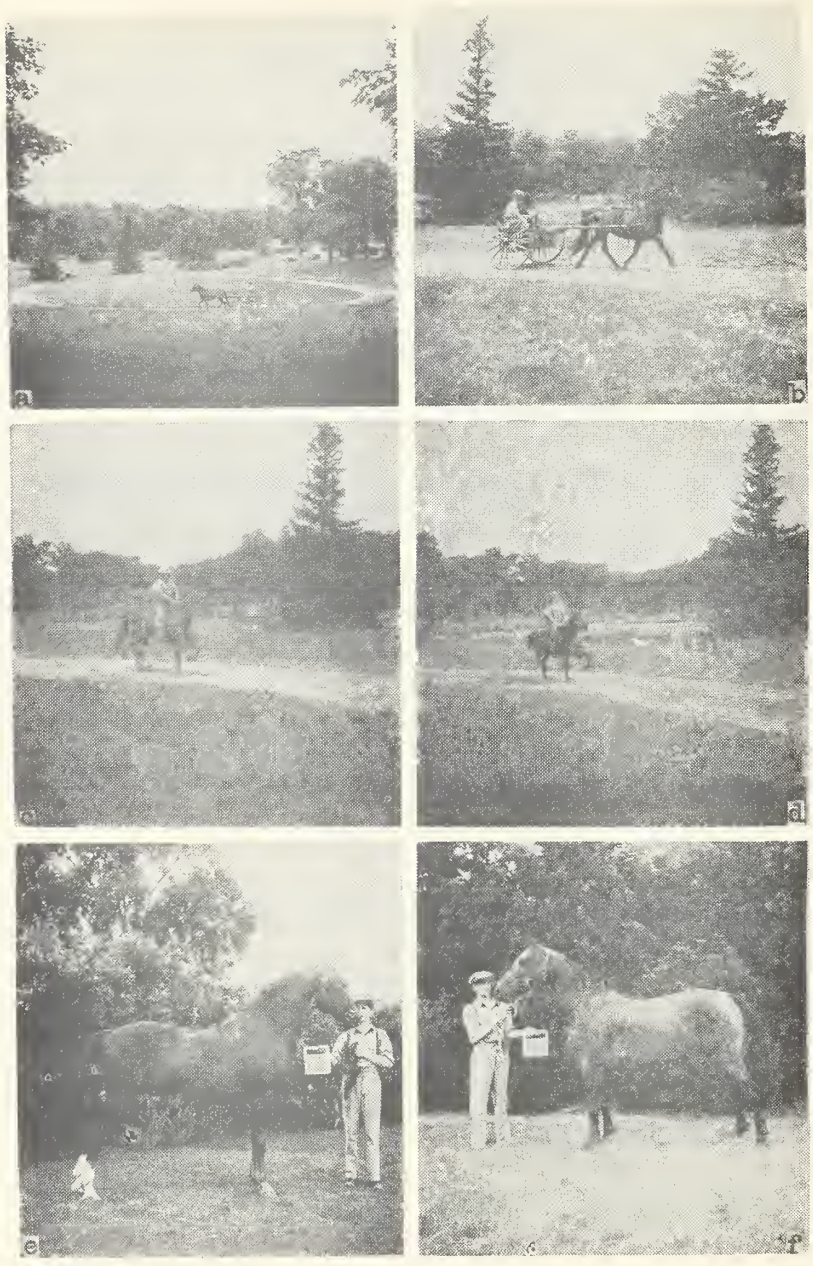

Figure 1. Equipment and some of the horses used in making the tests. (a) The training track, with Fairytop being tested at the trot in carriage. (b) The cart used for tests in carriage, with Ebony Maid being tested at the trot. (c) Fawn and (d) Damsel being tested at the trot in the saddle. (e) Mansfield and (f) Damsel, showing the type of horse used in the tests.

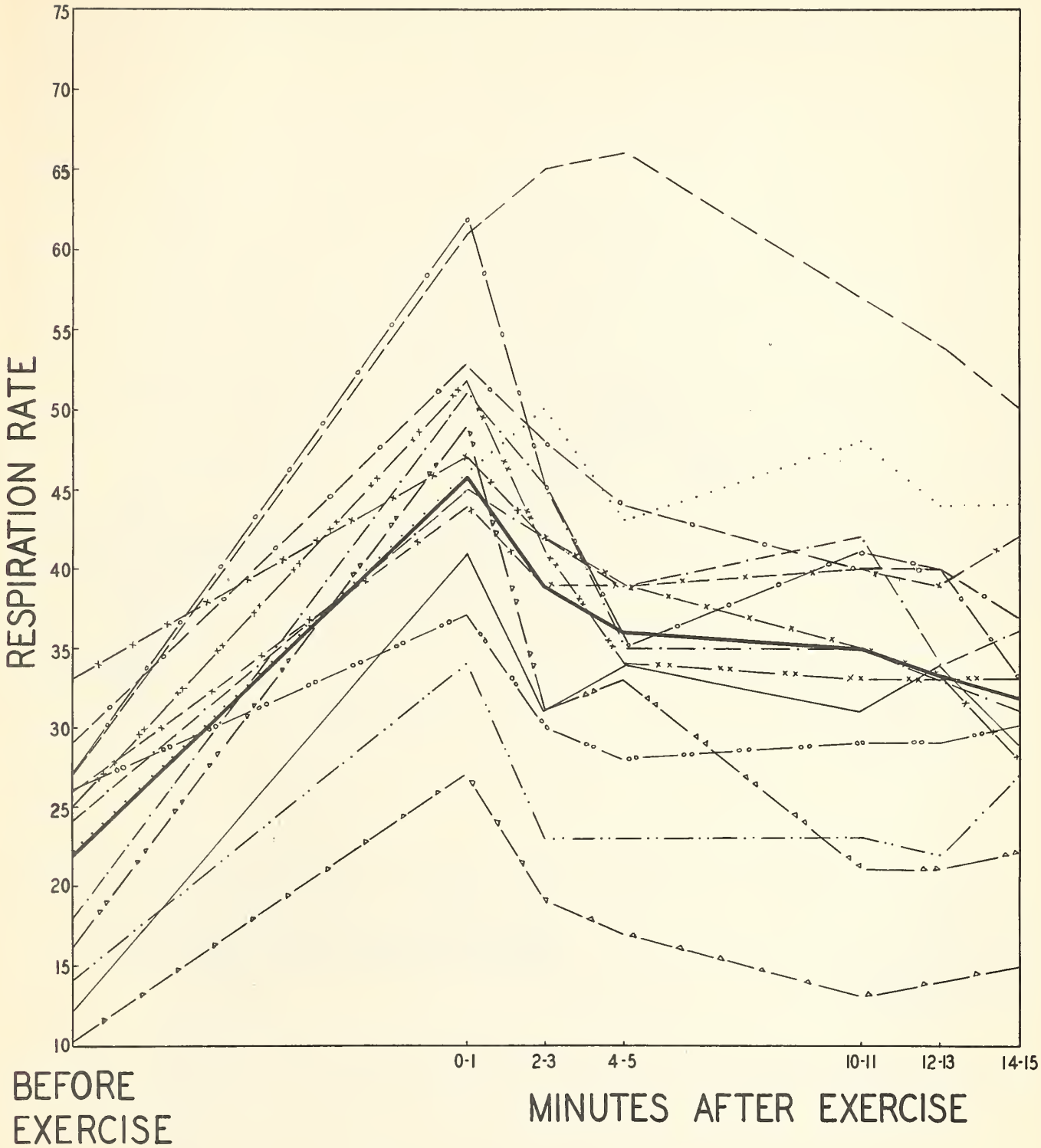

FIGURE 2.-RESPIRATION RATES BEFORE EXERCISE, INCREASES DUE TO WALKING ONE MILE IN CARRIAGE, AND CHANGES FOLLOWING EXERCISE.

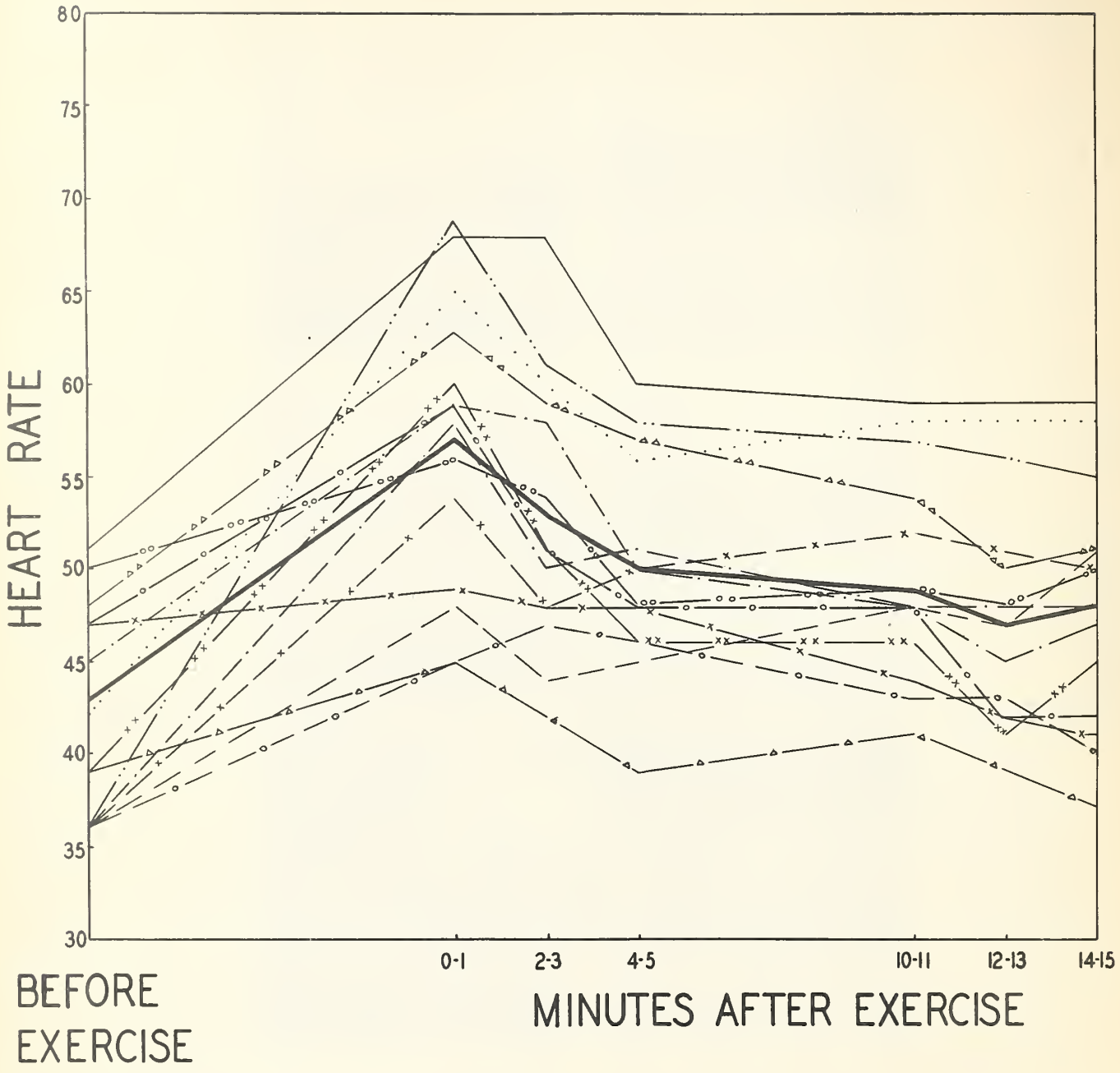

FIGURE 3.-HEART RATES BEFORE EXERCISE, INCREASES DUE TO WALKING ONE MILE IN CARRIAGE, AND CHANGES FOLLOWING EXERCISE.

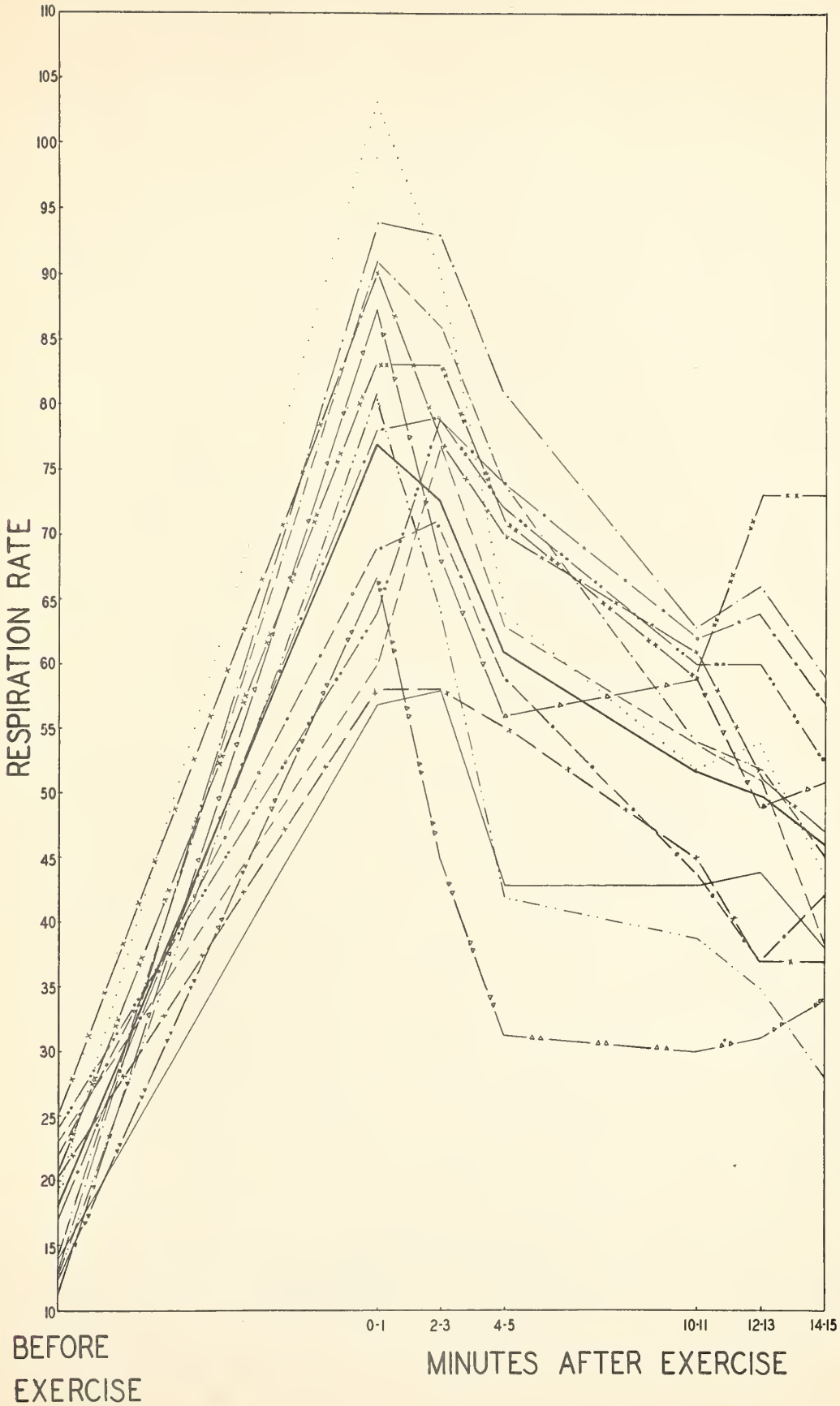

FIGURE 4.-RESPIRATION RATES BEFORE EXERCISE, INCREASES DUE TO TROTTING ONE MILE IN CARRIAGE, AND CHANGES FOLLOWING EXERCISE.

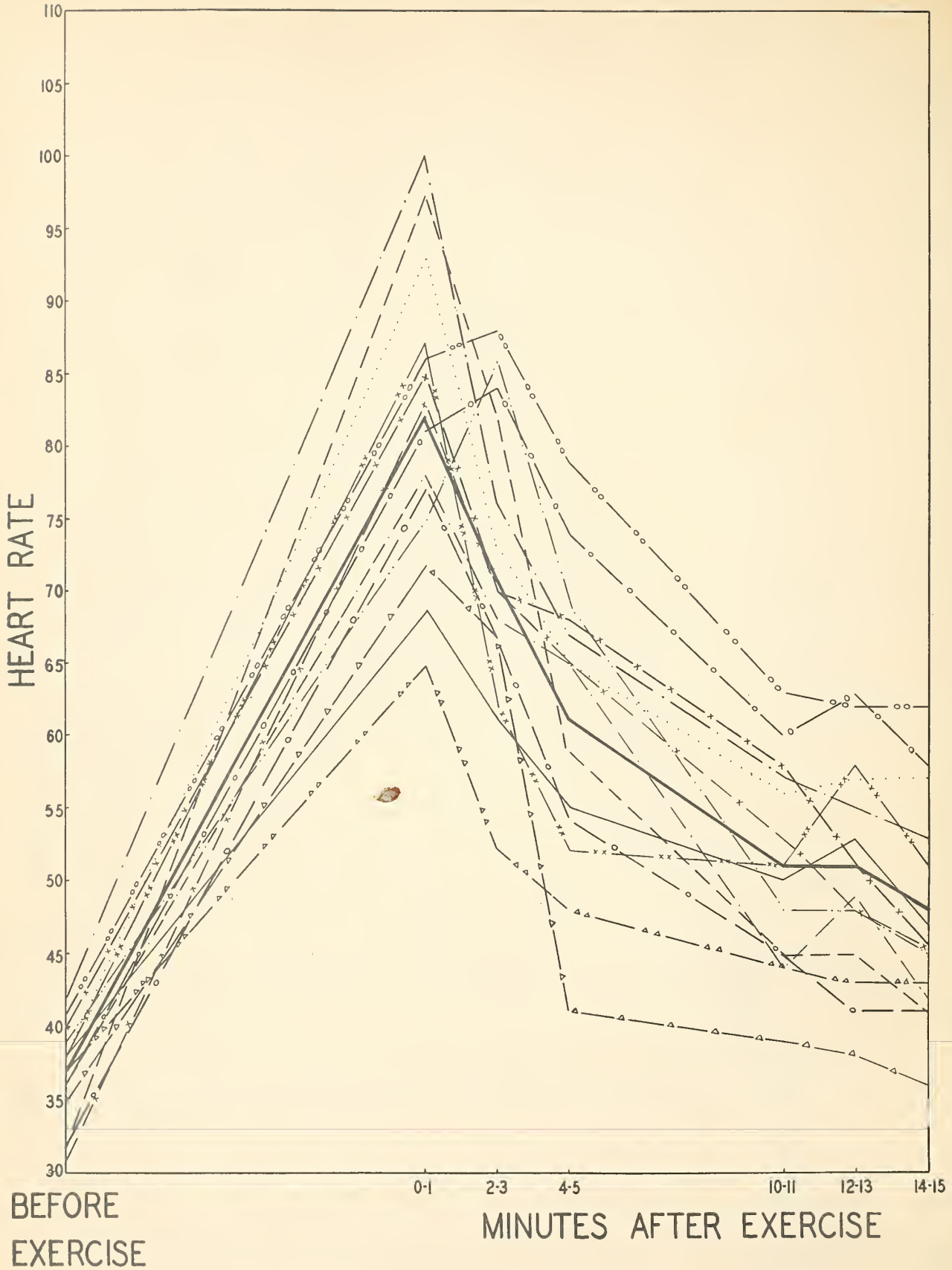

FIGURE 5.-HEART RATES BEFORE EXERCISE, INCREASES DUE TO TROTTING ONE MILE IN CARRIAGE, AND CHANGES FOLLOWING EXERCISE.